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10/623,674	07/21/2003	Steven D. Burch	GP-303298	5067
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CARY W. BROOKS General Motors Corporation Legal Staff, Mail Code 482-C23-B21 P.O. Box 300 Detroit, MI 48265-3000			AUSTIN, MELISSA J	
			ART UNIT	PAPER NUMBER
			1745	

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Please find below and/or attached an Office communication concerning this application or proceeding.

<b>Office Action Summary</b>	<b>Application No.</b> 10/623,674	<b>Applicant(s)</b> BURCH ET AL.	
	<b>Examiner</b> Melissa Austin	<b>Art Unit</b> 1745	

**-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --**

**Period for Reply**

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

**Status**

- 1) ☒ Responsive to communication(s) filed on 21 July 2003.
- 2a) ☐ This action is **FINAL**.                      2b) ☒ This action is non-final.
- 3) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

**Disposition of Claims**

- 4) ☒ Claim(s) 1-28 is/are pending in the application.
- 4a) Of the above claim(s) \_\_\_\_\_ is/are withdrawn from consideration.
- 5) ☐ Claim(s) \_\_\_\_\_ is/are allowed.
- 6) ☒ Claim(s) 1-18 and 20-28 is/are rejected.
- 7) ☒ Claim(s) 19 is/are objected to.
- 8) ☐ Claim(s) \_\_\_\_\_ are subject to restriction and/or election requirement.

**Application Papers**

- 9) ☐ The specification is objected to by the Examiner.
- 10) ☐ The drawing(s) filed on \_\_\_\_\_ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.  
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).  
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).
- 11) ☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

**Priority under 35 U.S.C. § 119**

- 12) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
- a) ☐ All    b) ☐ Some \*    c) ☐ None of:
1. ☐ Certified copies of the priority documents have been received.
2. ☐ Certified copies of the priority documents have been received in Application No. \_\_\_\_\_.
3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

\* See the attached detailed Office action for a list of the certified copies not received.

**Attachment(s)**

- |  |   |
|--|---|
| 1) <input checked="" type="checkbox"/> Notice of References Cited (PTO-892)                        | 4) <input type="checkbox"/> Interview Summary (PTO-413)                     |
| 2) <input type="checkbox"/> Notice of Draftsperson's Patent Drawing Review (PTO-948)               | Paper No(s)/Mail Date. _____  |
| 3) <input checked="" type="checkbox"/> Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) | 5) <input type="checkbox"/> Notice of Informal Patent Application (PTO-152) |
| Paper No(s)/Mail Date _____  | 6) <input type="checkbox"/> Other: _____                                    |

## DETAILED ACTION

### *Claim Objections*

1. Claim 19 is objected to under 37 CFR 1.75(c), as being of improper dependent form for failing to further limit the subject matter of a previous claim. Applicant is required to cancel the claim(s), or amend the claim(s) to place the claim(s) in proper dependent form, or rewrite the claim(s) in independent form. Claim 19, dependent on claim 1, requires all the steam be fed to the primary reactor. Claim 1 requires a primary reactor with feed inputs comprising steam and further states that the HT-PEMFC is adapted to generate *the steam needed* for the primary reactor (emphasis added). This claim reads that all the steam needed for the primary reactor is generated in the HT-PEMFC. If the steam needed for the primary reactor is generated in the HT-PEMFC, and the primary reactor has input of steam, then the generated steam must be the steam in the primary reactor input. Claim 19 fails to further limit claim 1 because the independent claim contains the limitation given in the dependent claim.

### *Claim Rejections - 35 USC § 112*

2. The following is a quotation of the second paragraph of 35 U.S.C. 112:

The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

Claims 7, 8, 16-18 are rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

3. The term "about" in claims 7, 8, 16-18 is a relative term which renders the claim indefinite. The term "about" is not defined by the claim, the specification does not provide a standard for ascertaining the requisite degree, and one of ordinary skill in the art would not be reasonably apprised of the scope of the invention. Regarding claims 7 and 8, the portion of steam recycled to the HT-PEMFC stack and the portion of steam used in the primary reactor are indefinite as defined by "about two-thirds to about one-half" and "about one-third to one-half," respectively. The anode stoichiometry, S:C, and O:C in claims 16,

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17, and 18, respectively, are indefinite as defined in ranges with bounds that are unclear. The use of the term "about" in defining the upper and/or lower bound of a range results in an open-ended range. This rejection can be overcome by amending the claims to define the ranges for steam stream division, anode stoichiometry, S:C, and O:C without the term "about."

4. A broad range or limitation together with a narrow range or limitation that falls within the broad range or limitation (in the same claim) is considered indefinite, since the resulting claim does not clearly set forth the metes and bounds of the patent protection desired. Note the explanation given by the Board of Patent Appeals and Interferences in *Ex parte Wu*, 10 USPQ2d 2031, 2033 (Bd. Pat. App. & Inter. 1989), as to where broad language is followed by "such as" and then narrow language. The Board stated that this can render a claim indefinite by raising a question or doubt as to whether the feature introduced by such language is (a) merely exemplary of the remainder of the claim, and therefore not required, or (b) a required feature of the claims. Note also, for example, the decisions of *Ex parte Steigewald*, 131 USPQ 74 (Bd. App. 1961); *Ex parte Hall*, 83 USPQ 38 (Bd. App. 1948); and *Ex parte Hasche*, 86 USPQ 481 (Bd. App. 1949). In the present instance, claim 16 recites the broad recitation "about 1.0 to about 1.3", and the claim also recites "about 1.1 to about 1.2" which is the narrower statement of the range/limitation. Also, claim 18 recites the broad recitation "about 0.6 to about 1.5", and the claim also recites "about 0.7 to about 0.8" which is the narrower statement of the range/limitation. This rejection can be overcome by amending the claims to include only one range each.

5. Claim 16 relates an anode stoichiometry to the primary reactor. The primary reactor does not have an anode; therefore, the requirement for the anode stoichiometry should not be directed to the reactor. The anode stoichiometry refers to the hydrogen fed to the fuel cell; it is suggested that the claim be amended to read, "the HT-PEMFC has an anode stoichiometry..." to reflect the corresponding statement on page 13 of the specification.

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***Claim Rejections - 35 USC § 102***

6. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless –

(a) the invention was known or used by others in this country, or patented or described in a printed publication in this or a foreign country, before the invention thereof by the applicant for a patent.

(b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

7. Claims 1, 2, 6, and 9 are rejected under 35 U.S.C. 102(b) as being anticipated by Grasso et al. (6,274,259) if the term “water” is interpreted to mean water in its vapor form, or steam.

The Grasso reference teaches a fuel cell power plant in which a reformer (Figure 1, 58: applicant's primary reactor), preferably an autothermal reformer but possibly a conventional steam reformer (pg. 4, [0033]), receives a reactant stream comprising fuel, air, and steam (Figure 1, 56, 54) used to produce a reformed fuel (Figure 1, 60: applicant's reformat). The reformed fuel is sent to a fuel cell or fuel cell stack (Figure 1, 14) with an electrolyte such as a proton exchange membrane (PEM) (pg. 3, [0030]) where it is used to generate electricity; this fuel cell is cooled by a water cooling loop that uses product water from the cell as the cooling liquid. The power plant also includes a catalytic burner (Figure 1, 40: applicant's catalytic combustor) that oxidizes excess reformed fuel from the anode exhaust of the fuel cell (Figure 1, 42; pg. 4, [0034]: applicant's excess hydrogen). The exhaust from this burner (Figure 1, 52) is sent to a steam generator (Figure 1, 50) to produce steam from a water supply, including a portion of the cooling stream exiting the fuel cell (Figure 1, 84), for the reforming reaction and, as such, provide the reactant (Figure 1, 54) at a temperature appropriate for the reaction in the reformer. Additionally, the steam generator may be unnecessary as adequate water (interpreted as adequate in terms of quantity and quality; steam) may be supplied by fuel cell means (pg. 4, [0032]) and may be sent directly to the burner or reformer (pg. 4, [0034]); that is, the water (steam) generated by the fuel cell cooling loop may be sufficient for the reaction in the reformer so that an additional water supply is unnecessary. It is noted that applicant requires a high temperature proton exchange membrane fuel cell

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(HT-PEMFC); this requirement is met in the Grasso reference's "electrolyte such as a proton exchange membrane (PEM)" (pg. 3, [0030]). An HT-PEMFC electrolyte is a proton exchange membrane.

8. Claims 21, 22, and 28 rejected under 35 U.S.C. 102(b) as being anticipated by Eggert et al. (Characteristics of Indirect-Methanol Fuel Cells). Figure 1 of the Eggert reference shows a reformer (applicant's primary reactor) with a reactant stream of steam and fuel that generates a reformat. The reformat is fed to a PEM fuel cell stack (pg. 1327) that uses the reformat to produce electrical power. The fuel cell stack is water cooled, and the water and thermal management of the fuel cell maintains water self-sufficiency of the system, including water for steam reformation (pg. 1330). An evaporator (applicant's primary reactor heat exchanger) for transferring heat energy from the reformat to the reactant steam is positioned between the reformer and a water-gas-shift reactor. A catalytic burner (applicant's catalytic combustor) burns anode exhaust, fuel, and air to supply heat energy to the reformer and super heaters (applicant's superheat heat exchanger) for superheating the fuel and steam before they are reacted in the reformer. It is noted that applicant requires a high temperature proton exchange membrane fuel cell (HT-PEMFC); this requirement is met in the Eggert reference's proton exchange membrane (PEM) (pg. 1327). An HT-PEMFC employs a proton exchange membrane.

***Claim Rejections - 35 USC § 103***

9. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

10. Claim 1, 2, 3, 6, 7, 8, 9, 13, and 14 are rejected under 35 U.S.C. 103(a) as being unpatentable over Grasso et al (6,274,259) in view of Bloomfield (3,982,962) if the term "water" in the Grasso reference is interpreted to be water in its liquid or partially vaporized state.

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The Grasso reference teaches a fuel cell power plant in which a reformer (Figure 1, 58: applicant's primary reactor), preferably an autothermal reformer but possibly a conventional steam reformer (pg. 4, [0033]), receives a reactant stream comprising fuel, air, and steam (Figure 1, 56, 54) that is used to produce a reformed fuel (Figure 1, 60: applicant's reformat). The reformed fuel is sent through a water shift reactor (Figure 1, 64: applicant's water gas shift (WGS) reactor) to a fuel cell or fuel cell stack (Figure 1, 14: applicant's HT-PEMFC) with an electrolyte such as a proton exchange membrane (PEM) (pg. 3, [0030]) where it is used to generate electricity. It is noted that applicant requires a high temperature proton exchange membrane fuel cell (HT-PEMFC); this requirement is met in the Grasso reference's "electrolyte such as a proton exchange membrane (PEM)" (pg. 3, [0030]). An HT-PEMFC electrolyte is a proton exchange membrane. The power plant also includes a catalytic burner (Figure 1, 40: applicant's catalytic combustor) that oxidizes excess reformed fuel from the anode exhaust of the fuel cell (Figure 1, 42; pg. 4, [0034]: applicant's excess hydrogen). However, the reference fails to teach generation of steam by the fuel cell stack for use in the primary reactor, a heat exchanger between the primary reactor and fuel cell stack for heating steam with reformat heat, or the use of a catalytic combustor burning excess hydrogen to maintain the temperature in the primary reactor.

The Bloomfield reference teaches a fuel cell power plant containing a fuel cell thermal management portion (Figure 1, 25) in which water flows to cool the fuel cell. This water is at least partially vaporized (turned to steam) in this process (Col. 5, ln 28-33). This water/steam then flows through several heat exchange operations including a heat exchanger (Figure 1, 72: applicant's primary reactor heat exchanger) positioned between the steam reforming reactor (Figure 1, 18: applicant's primary reactor) and the shift converter (Figure 1, 16: applicant's WGS reactor) that transfers heat from the processed fuel (Figure 1, 70: applicant's reformat) to the water/steam stream from the thermal management portion of the fuel cell before it is mixed with fuel and fed to the steam reforming reactor. The power plant also includes a burner (Figure 1, 20: applicant's catalytic combustor) that oxidizes excess reformed fuel from the anode effluent gas of the fuel cell (Figure 1, 78, 82: applicant's excess hydrogen). Heat for the steam reforming reactor is provided by the burner by passing the burner effluent gases (Figure 1, 86) in a heat exchange relationship with the reactor (Col. 5, ln 2-6).

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Both Grasso and Bloomfield teach the use of steam generated in the fuel cell being divided for use between the reformer and the fuel cell cooling loop. Grasso teaches that a portion of the cooling water (Figure 1, 84) is diverted to the reformer (Figure 1, 58) through a steam generator (Figure 1, 50) after exiting the fuel cell. The remaining portion of the cooling water (Figure 1, 72) is recycled through the cooling loop. In some cases, the steam generator is unnecessary because "adequate water" (interpreted as adequate in terms of quantity and quality) is supplied by the fuel cell means. The water may be sent directly to the reformer (pg. 4, [0032], [0038]). Bloomfield teaches water that is at least partially vaporized as it is sent through the fuel cell in a heat exchange relationship. This water/steam then flows through several heat exchange relationships where it is completely vaporized and superheated before being delivered to a valve (Figure 1, 96). This valve permits the amount of steam necessary for the reforming reactor into stream 66; the remainder of the steam is delivered back to the cooling loop via a turbine and condenser in order to feed the water to the cooling loop in the liquid phase. (Col. 5, ln 28-60) Although neither reference speaks to the fraction of the steam stream that is recondensed for use in the fuel cell cooling loop or the fraction sent to the reformer, one of ordinary skill in the art would be familiar with the amount of steam needed for the reforming reaction and for adequate cooling of the stack.

The Bloomfield reference teaches air cooled condensers (Figure 1, 80, 54) for both the anode and cathode exhaust streams (Figure 1, 78, 52) and the remainder of the steam (Figure 1, 104) not needed in the reforming reactor (applicant's anode and cathode exhaust condensers and excess steam condenser). These condensers recover water to be recycled to the fuel cell cooling loop. Bloomfield also discloses an air stream delivered to the fuel cell cathode (Figure 1, 50) via a compressor (Figure 1, 38) with an air inlet (Figure 1, 44). One skilled in the art of plant design and optimization would realize that the cooling air from the anode and cathode exhaust stream condensers and excess steam condenser could be cycled to the compressor inlet and, in so doing, reduce the utility cost of the fuel cell power plant by decreasing the external air brought into the plant.

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have combined the reformer with a reactant stream comprising steam, air, and fuel to produce a reformed fuel; WGS reactor; catalytic combustor for anode exhaust; and PEM fuel cell stack

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taught by Grasso et al. with the thermal management portion of the fuel cell for generating steam for use in the reformer; heat exchanger for transferring heat from the reformed fuel to the generated steam; anode exhaust burner effluent gases for heating the reformer reactor; and anode and cathode exhaust stream and excess steam air-cooled condensers and air compressor to feed the fuel cell (with condenser air used to supply the compressor as generally known in design and optimization) as taught by Bloomfield and the division of the steam stream generated by the fuel cell to the reformer and cooling loop taught by both references in order to reduce the utility cost associated with operating the fuel cell power plant. The use of the water/steam from the thermal management portion of the fuel cell to provide water for the reformer and the cooling loop, use of the processed fuel heat to heat the water/steam, use of a catalytic combustor to burn the anode exhaust/excess hydrogen for heating the reformer reactor, use of condensers to recover water from the anode and cathode exhaust streams and excess steam stream for use in the cooling loop, and use of the cooling air in the condensers as the feed to the air compressor are economically advantageous strategies as they reduce the overall utility cost associated with this power plant by decreasing the amount of external water and air that must be supplied and the material or equipment that would be needed to provide heat, and they allow for efficient thermal management within the fuel cell power plant.

11. Claim 4 is rejected under 35 U.S.C. 103(a) as being unpatentable over Grasso et al. (6,274,259) and Bloomfield (3,982,962) as applied to claim 1 above, and further in view of Beshty et al. (4,670,359). The Grasso and Bloomfield references teach the elements of claim 1, including a catalytic burner that burns anode exhaust of the fuel cell (applicant's excess hydrogen) but fail to disclose a superheat heat exchanger to heat the reactant steam before introduction to the primary reactor using heat energy from a catalytic combustor. Beshty teaches a mixture of water and methanol fuel (Figure 2, 26A) fed to a heat exchanger (Figure 2, 26) where it is superheated before continuing to the reformer (Figure 2, 23: applicant's primary reactor). A burner (Figure 2, 47) supplies combustion products (Figure 2, 49: applicant's heat energy) to the heat exchanger for heat energy to be transferred to the water/fuel mixture by burning the anode exhaust of the fuel cell (applicant's excess hydrogen). (Col. 6, ln 64 – Col. 7, ln 3)

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The superheated water/fuel mixture contains enough sensible heat for the endothermic reforming reaction to proceed with little, if any, external heat input. (Col. 6, ln 10-14) Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have included in the fuel cell power plant as disclosed by Grasso et al. and Bloomfield a heat exchanger for superheating the fuel and water to be fed into a reformer using the exhausted combustion products from a burner that burns the anode exhaust of the fuel cell as taught by Beshty et al., said burner being a catalytic burner as taught by Grasso et al., for the purpose of reducing the external heat input necessary to stimulate the endothermic reforming reaction and for efficient thermal management within the fuel cell power plant.

12. Claim 5 is rejected under 35 U.S.C. 103(a) as being unpatentable over Grasso et al. (6,274,259) and Bloomfield (3,982,962) as applied to claim 1 above, and further in view of Towler et al. (6,375,924). The Grasso and Bloomfield references teach the elements of claim 1 but fail to disclose a WGS reactor heat exchanger in fluid communication between a WGS reactor and the HT-PEMFC stack adapted to heat steam before being used in the primary reactor with the heat energy of the reformat. It should be noted that the phrase "adapted to" is interpreted as "capable of." Towler discloses a shift effluent cooler (Figure 1, 61: applicant's WGS reactor heat exchanger) receiving a shift effluent stream (Figure 1, 60: applicant's gaseous reformat) from a shift reaction zone (applicant's WGS reactor) where it heats and partially vaporizes, by indirect heat exchange, a deionized water stream (Figure 1, 40). (Col. 12, ln 16-27) The shift effluent stream then continues to the fuel cell (Figure 1, streams 60', 71, fuel cell 72). While the Towler reference does not teach that the water stream is that which has been used in cooling the fuel cell, the shift effluent cooler would be capable of receiving and heating such a stream in place of the deionized water stream disclosed. The cooler works to decrease the temperature of the effluent stream to effective oxidation conditions and to heat and partially vaporize the water stream. Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have included a heat exchanger as taught by Towler et al. to heat the water/steam being sent to the reformer between the WGS reactor and the fuel cell stack taught by Grasso et al. and Bloomfield with reformat heat so that

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less additional equipment and heating utilities would be necessary for efficient thermal management within the fuel cell power plant.

13. Claim 10 is rejected under 35 U.S.C. 103(a) as being unpatentable over Grasso et al. (6,274,259) and Bloomfield (3,982,962) as applied to claim 1 above, and further in view of Clawson et al. (US 2002/0004152 A1) as evidenced by Baukal, Jr. (Heat Transfer in Industrial Combustion). The Grasso and Bloomfield references teach the elements of claim 1 but fail to teach a catalytic combustor in fluid communication with a combustor air preheat exchanger which is adapted to receive heat energy from combustor exhaust and to preheat air used in the catalytic combustor. Clawson et al. teach a catalytic burner (Figure 1, 14: applicant's catalytic combustor) that receives an air and steam stream, a fuel stream, and recycled anode exhaust (Figure 1, 12, 14, 16). The air/steam stream has been heated in a heat exchanger (Figure 1, 34: applicant's air preheat heat exchanger) with heat energy from the catalytic burner exhaust stream (Figure 1, 30: applicant's burner exhaust). This heat exchange serves to recover most of the heat from the burner exhaust and prepare it for condensation to recover water (pg. 5, [0066]). Baukal, Jr. teaches that available heat in a combustion system is increased with oxidizer preheat temperature resulting in fuel savings (2.2.3 Available Heat). Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have included the catalytic burner and heat exchanger as taught by Clawson et al. in the fuel cell power plant as taught in the Grasso et al. and Bloomfield references in order to recover and use the excess hydrogen in the anode exhaust stream, cool the combustor exhaust before discharging it from the plant, and reduce the fuel and utility cost associated with the operating the fuel cell power plant.

14. Claims 11 and 20 are rejected under 35 U.S.C. 103(a) as being unpatentable Grasso et al. (6,274,259) and Bloomfield (3,982,962) over as applied to claim 1 above, and further in view of Buswell et al. (5,360,679).

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15. With respect to claim 11, the Grasso and Bloomfield references teach the elements of claim 1 but fail to teach exhaust liquid separators to recover water from the anode and cathode exhausts from the HT-PEMFC. The Buswell reference teaches that entrained water in the anode and cathode exhaust streams exiting the fuel cell stack is removed by water separators (Figure 1, 188 and 189), and the recovered water is sent to a water tank (Figure 1, 192) for use in the water recovery subsystem that, among other things, provides cooling water to the cell, as it recycles water produced in the fuel cell stack (Col. 10, ln 10-16, 38-43; Col. 5, ln 14-25). Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to include in the fuel cell power plant as disclosed by Grasso et al. and Bloomfield the anode and cathode exhaust separators as taught by Buswell et al. for the purpose of recovering entrained water from the exhaust for use in other plant systems, and, therefore, reducing the amount of external water needed to carry out the operation and the associated utility cost.

16. Regarding claim 20, the Grasso and Bloomfield references teach the elements of claim 1 but fail to teach a water/steam separator to remove excess water from the reformat before it is fed to the fuel cell stack. Bloomfield also teaches that fuel cells perform better at higher reactant pressures (Col. 1, ln 23-24). Buswell teaches a water separator (Figure 1, 182) that removes condensed water from the reformat fuel stream (Figure 1, 14) before it is sent to the fuel cell stack (Figure 1, 186). Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to include a separator as taught by Buswell et al. in the fuel cell power plant as disclosed by Grasso et al. and Bloomfield in order to remove condensed water from the reformat before its use in the fuel cell stack. The reaction at the anode of the fuel cell is gaseous and removal of condensed water before this reaction is advantageous from a reaction and efficiency standpoint, as taught by Bloomfield in that performance is better at higher reactant pressures.

17. Claim 12 is rejected under 35 U.S.C. 103(a) as being unpatentable over Grasso et al. (6,274,259) and Bloomfield (3,982,962) as applied to claim 1 above, and further in view of Okada et al. (5,302,470). The Grasso and Bloomfield references teach the elements of claim 1 but fail to teach a stack coolant

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liquid separator to separate liquid water from the steam exiting the HT-PEMFC stack. The Okada reference discloses a gas/water separator (Figure 1, 18: applicant's stack coolant liquid separator) for the cooling water circulated from the fuel cell stack where the water is recycled to the cooling loop and the steam is sent to the reformer (Col. 2, ln 52-60). Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to add the gas/water separator for separation of liquid water and steam from the fuel cell cooling loop as taught by Okada et al. to the fuel cell power plant as disclosed by Grasso et al. and Bloomfield in order to decrease the amount of external water necessary for plant operation and, in so doing, reduce the utility cost for the plant.

18. Claim 15 is rejected under 35 U.S.C. 103(a) as being unpatentable over Grasso et al. (6,274,259) and Bloomfield (3,982,962) as applied to claim 1 above, and further in view of Van Dine et al. (6,331,366). The Grasso and Bloomfield references teach the elements of claim 1 but fail to teach a heat exchanger in which the reformat is used to heat the anode exhaust before it is fed to the fuel cell stack. The Van Dine reference teaches a second heat exchanger (Figure 1, 62: applicant's anode exhaust preheat heat exchanger) in which the anode exhaust (Figure 1, 42) is heated by the reformed fuel (Figure 1, 54: applicant's reformat). The reformed fuel then continues to the fuel cell and the anode exhaust is combusted in a catalytic burner. Preheating the anode exhaust allows for efficient combustion in the burner so that the exhaust stream leaving the burner is non-flammable (Col. 13, ln 7-13 and Col. 7, ln 18-22). Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have included in the fuel cell power plant as disclosed by Grasso et al. and Bloomfield a heat exchanger for providing greater heat input to the anode exhaust by the reformed fuel in order to more efficiently combust the anode exhaust in the combustor and produce a non-flammable combustor exhaust stream as taught by Van Dine et al. This heat exchanger also provides heat integration within the plant thereby reducing utility costs and efficiency for the plant. The production of a non-flammable combustor exhaust stream is also environmentally advantageous.

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19. Claim 16 is rejected under 35 U.S.C. 103(a) as being unpatentable over Grasso et al. (6,274,259) and Bloomfield (3,982,962) as applied to claim 1 above, and further in view of Hallum et al. (US 2002/0081466) and Cownden et al. (US 2002/0015870 A1). The Grasso and Bloomfield references teach the elements of claim 1 but fail to teach an anode stoichiometry. The Hallum reference teaches that the fuel (hydrogen) and air flow to the fuel cell stack must be sufficient to meet appropriate stoichiometric ratios to meet a given output power (pg. 1, [0005]); that is, the fuel feed is 100% of the theoretical fuel needed for the reaction, or an anode stoichiometry of 1.0. Hallum also teaches that due to the nonideality of the fuel cell stack, not all of the fuel fed to the stack will react (pg. 5, [0006]) so the feed rate may need to be increased to effect better fuel and power efficiency.

Figure 3 A of the Cownden reference provides the flow rates of fluid streams during a steady-state operating mode (pg. 7, [0098]). Streams 13 and 14 are the hydrogen-rich fuel (anode inlet) and anode exhaust streams, respectively, as shown on Figure 2. From the entries for these streams in the H<sub>2</sub> (lbmol/h) column of the table shown in Figure 3A (column 5), the amount of excess hydrogen can be calculated:

$$\text{H}_2 \text{ used in fuel cell anode reaction (theoretical hydrogen)} = \frac{\text{H}_2 \text{ in (stream 13)} - \text{H}_2 \text{ out (stream 14)}}{(17.90 - 3.56) \text{ lbmol/hr}} = 14.34 \text{ lbmol/hr}$$

$$\% \text{ excess H}_2 \text{ fed to anode} = \frac{\{[(\text{H}_2 \text{ fed to anode}) \div (\text{H}_2 \text{ used in fuel cell anode reaction})] - 1.0\} \times 100\%}{[(17.90 \div 14.34) - 1.0] \times 100\%} = 25.6\%$$

The Cownden reference therefore teaches 25.6% excess H<sub>2</sub> in the feed to the anode of the fuel cell. This is an anode stoichiometry of 1.26. Cownden also teaches that 50-90% of the hydrogen in the reformat stream is consumed in the fuel cell stack (pg. 9, [0130]), thus illustrating the need for feeding hydrogen in 10-50% excess, or an anode stoichiometry of 1.1 to 1.5, to achieve a desired output.

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have used an anode stoichiometry between 1.0 and 1.5 as taught by Hallum et al. and Cownden et al. in the fuel cell power plant as disclosed by Grasso et al. and Bloomfield in order to reach the desired power output from the fuel cell.

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20. Claim 17 is rejected under 35 U.S.C. 103(a) as being unpatentable over Grasso et al. (6,274,259) and Bloomfield (3,982,962) as applied to claim 1 above, and further in view of Cutright et al. (US 2002/0160239 A1) and Okada et al. (5,302,470). The Grasso and Bloomfield references teach the elements of claim 1 but fail to teach a ratio of steam to fuel carbon (S:C) for the primary reactor. The Cutright reference teaches a molar ratio of water (steam) to methane (fuel carbon) in the reactor (reformer) in the range of 2.0 to 5.0 (pg. 3, [0026]). The Okada reference teaches that S:C can affect the amount of carbon monoxide and hydrogen produced in the reforming reaction and deposition of carbon on the reforming catalyst. Decreasing S:C increases the hydrogen partial pressure, which in turn improves the efficiency of power generation in the fuel cell. This decrease in S:C also results in an increase of CO in the fuel gas that persists through shift reactions to remove it, and the CO poses a risk to the catalyst of the fuel electrode (applicant's anode) of the fuel cell. Okada discloses ranges of S:C operation for Ru and Ni reforming catalysts:  $S:C_{Ru} = 0.7-2.5$ ,  $S:C_{Ni} = 1.5-3.5$ , and also notes that S:C is commonly adjusted to more than 3 and more than 4 with the Ru and Ni catalysts, respectively (Col. 3, In 31 – Col. 4, In 30, 59-62). Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have used a steam to fuel carbon ratio between 2 and 5 as taught by Cutright et al. and Okada et al. in the fuel cell power plant as disclosed by Grasso et al. and Bloomfield in order to improve the efficiency of power generation in the fuel cell while reducing the deposition of carbon on the reforming catalyst and fuel cell anode poisoning by CO.

21. Claim 18 is rejected under 35 U.S.C. 103(a) as being unpatentable over Grasso et al. (6,274,259) and Bloomfield (3,982,962) as applied to claim 1 above, and further in view of Kunitake et al. (US 2002/0046889 A1). The Grasso and Bloomfield references teach the elements of claim 1 but fail to teach a ratio of atomic oxygen in the air flow to carbon in the fuel flow (O:C) in the primary reactor. The Kunitake reference teaches a method for removing carbon deposited on the steam reforming catalyst by adjusting the O:C ratio (Abstract). The O:C ratio in a fuel cell system in steady operating mode is held in the range 0.7–1.0, and the ratio is increased to execute the carbon removal process (pg. 4, [0051], examples). The value of O:C for each example is different due to the conditions under which the carbon removal process

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is being run: Example 1, 2, 4 = 1.5, Example 3 ~ 1.75, Example 5 = infinity, Example 6 = peak of 4.8 (Figures 3B, 11B, 12B, 14B, 15B (pg 7, [0081]), 17B). Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have used an O:C ratio at steady conditions between 0.7 and 1.0 and while removing carbon from the reforming catalyst at an elevated O:C as shown in the examples of Kunitake et al. in the fuel cell power plant as disclosed by Grasso et al. and Bloomfield in order to remove the deposited carbon from the reforming catalyst so that catalytic activity is not deteriorated by accumulation of carbon.

22. Claims 23 and 24 are rejected under 35 U.S.C. 103(a) as being unpatentable over Eggert et al. in view of Okamoto (US 2002/0177016 A1). The Eggert reference teaches the elements of claim 21 and teaches that the superheated steam is mixed with a superheated fuel before being used in the primary reactor, but the reference fails to disclose the addition of compressed air to the superheated stream. Okamoto teaches a stream of air supplied to the reformer (Figure 1, 6: applicant's primary reactor) from a compressor in the air supply device (Figure 1, 11). The compressed air promotes water vapor reformate reactions and partial oxidation reactions (pg. 2, [0027]). Although the diagram does not show the superheated stream and compressed air stream being mixed before entering the reformer, they must be mixed prior to use within the reformer. Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to mix the superheated reactant stream containing fuel and steam from the super heaters as taught by Eggert et al. with compressed air as taught by Okamoto in order to promote water vapor reformate reactions and partial oxidation reactions.

23. Claim 25 is rejected under 35 U.S.C. 103(a) as being unpatentable over Eggert et al. in view of Towler et al. (6,375,924). The Eggert reference teaches the elements of claim 21 as well as a CO clean-up unit consisting of a water-gas-shift reactor and preferential oxidation unit (applicant's CO-polishing stage) (pg 1327). However, the reference fails to teach a WGS heat exchanger in fluid communication with the WGS reactor. Towler discloses a shift effluent cooler (Figure 1, 61: applicant's WGS heat exchanger) receiving a shift effluent stream (Figure 1, 60: applicant's gaseous reformate) from a shift

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reaction zone (Figure 1, 44: applicant's WGS reactor) that heats and partially vaporizes, by indirect heat exchange, a deionized water stream (Figure 1, 40) (Col. 12, ln 16-27). The cooler works to decrease the temperature of the effluent stream to effective oxidation conditions and to heat and partially vaporize the water stream. Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have included a shift effluent cooler as taught by Towler et al. to cool the shift effluent stream to effective oxidation conditions between the water-gas-shift reactor and preferential oxidation unit as taught by Eggert et al.

24. Claim 26 is rejected under 35 U.S.C. 103(a) as being unpatentable over Eggert et al. in view of Grasso et al. (6,274,259), as evidenced by Baukal, Jr. (Heat Transfer in Industrial Combustion). The Eggert reference teaches the elements of claim 21 but fails to disclose a heat exchanger to preheat the anode exhaust before it enters a combustor with the combustor exhaust. The Grasso reference teaches an anode exhaust heat exchanger (Figure 1, 44: applicant's anode exhaust preheat heat exchanger) receiving an anode exhaust stream (Figure 1, 42) and passing it in a heat exchange relationship with oxidized anode exhaust (Figure 1, 46: applicant's combustor exhaust) before sending the anode exhaust to the a burner (Figure 1, 40" applicant's combustor). Baukal, Jr. teaches that preheating fuel fed to a combustor increases the adiabatic flame temperature. This, in turn, increases the radiation and convection from the combustion products because they are at higher temperatures (which increases radiation), the transport properties change, and the product gas velocity increases (which increases convection) (8.4.1.4 Fuel Temperature). Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have included in the fuel cell system as disclosed by Eggert et al. the anode exhaust heat exchanger and anode exhaust burner as disclosed by Grasso et al. in order to increase the heat transfer from combustion products to the load. The use of burner exhaust as the heating fluid in a heat exchanger that heats the fuel fed to the burner for combustion is an economically advantageous strategy that reduces the overall utility cost associated with this power plant by decreasing the amount of material or equipment that would be needed to provide heat and for efficient thermal management within the fuel cell power plant.

25. Claim 27 is rejected under 35 U.S.C. 103(a) as being unpatentable over Eggert et al. in view of Van Dine et al. (US 2003/0027025 A1). The Eggert reference teaches the elements of claim 21 but fails to disclose a water injector for providing the required steam to the primary reactor. The Van Dine reference teaches the injection of liquid phase water into a heated hydrocarbon stream. The heat of the hydrocarbon stream, which has been passed through a heat exchanger, vaporizes the water to provide a hydrocarbon/steam mixture. These heating and injection steps can be repeated to reach the desired S:C (pg. 2, [0026], [0029]). Any injected water that is not vaporized by the heat in the hydrocarbon stream would be vaporized in the subsequent heat exchanger. Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have included a water injector as taught by Van Dine et al. to put water in the reactant stream before entering the super heater in order to provide the desired S:C at the reformer.

### ***Conclusion***

26. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.

Vollmar et al.	6,162,556	Dec. 19, 2000	water injector
Forte et al.	US2003/0017373	Jan. 23, 2003	catalytic combustor, separator, condenser
Goebel et al.	US 2002/0168316	Dec. 14, 2002	reformer, reactants, WGS, PR heat exchanger
Misumi	US 2003/0064263	Apr. 3, 2003	stack condenser, water from FC to reformer
Noguchi et al.	4,622,275	Nov. 11, 1986	superheated steam, air preheat

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Melissa Austin whose telephone number is (571) 272-1247. The examiner can normally be reached from 7:15 am – 3:45 pm (EST).

If attempts to reach the examiner by phone are unsuccessful, the examiner's supervisor, Patrick Ryan, can be reached at (571) 272-1292. The fax number for the organization where the application proceeding is assigned is (703) 872-9306.

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